



(56)

**References Cited**

U.S. PATENT DOCUMENTS

2012/0033119 A1\* 2/2012 Shinohara ..... 348/302  
 2012/0202307 A1\* 8/2012 Suzuki et al. .... 438/57  
 2012/0217602 A1\* 8/2012 Enomoto ..... 257/432  
 2012/0224096 A1 9/2012 Shimoda et al.  
 2013/0021499 A1 1/2013 Ui et al.

FOREIGN PATENT DOCUMENTS

JP 2010-213253 9/2010

JP 2012-169530 A 9/2012  
 JP 2012-182332 9/2012  
 KR 10-2013-0066565 A 6/2013  
 TW 201225276 A1 6/2012  
 TW 201316760 A1 4/2013

OTHER PUBLICATIONS

Office Action issued May 26, 2015 in Taiwanese Patent Application  
 No. 102144048 (with English translation).

\* cited by examiner

FIG.1

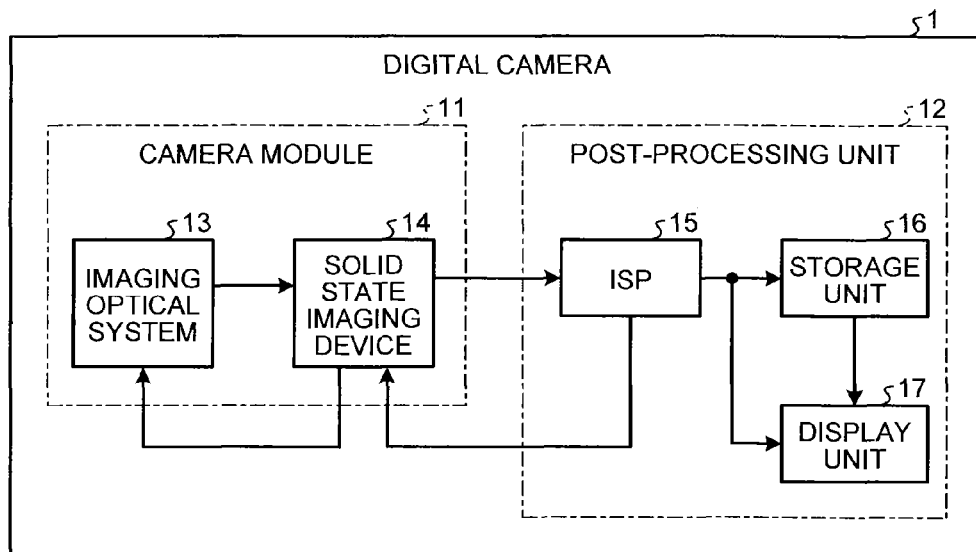


FIG.2

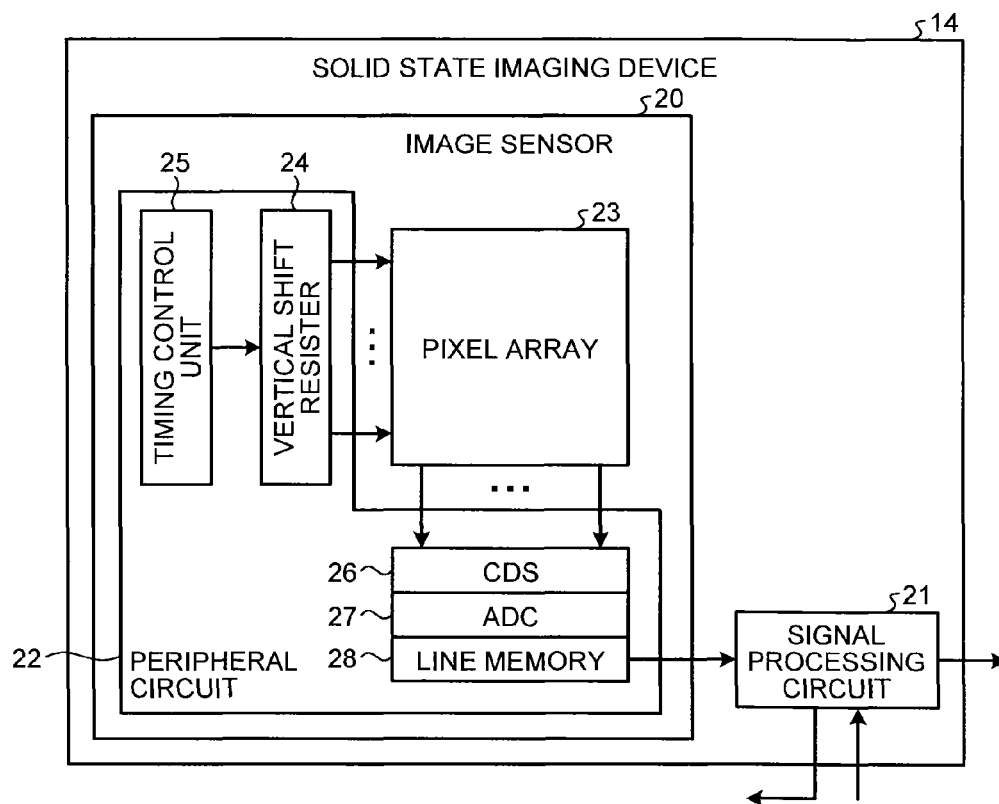


FIG.3

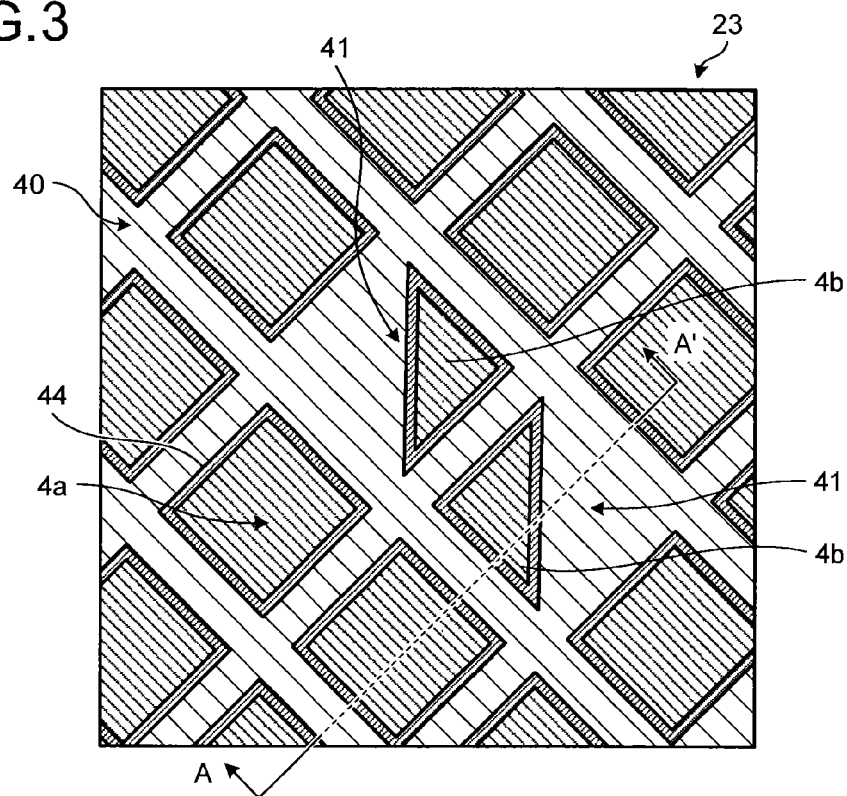


FIG.4

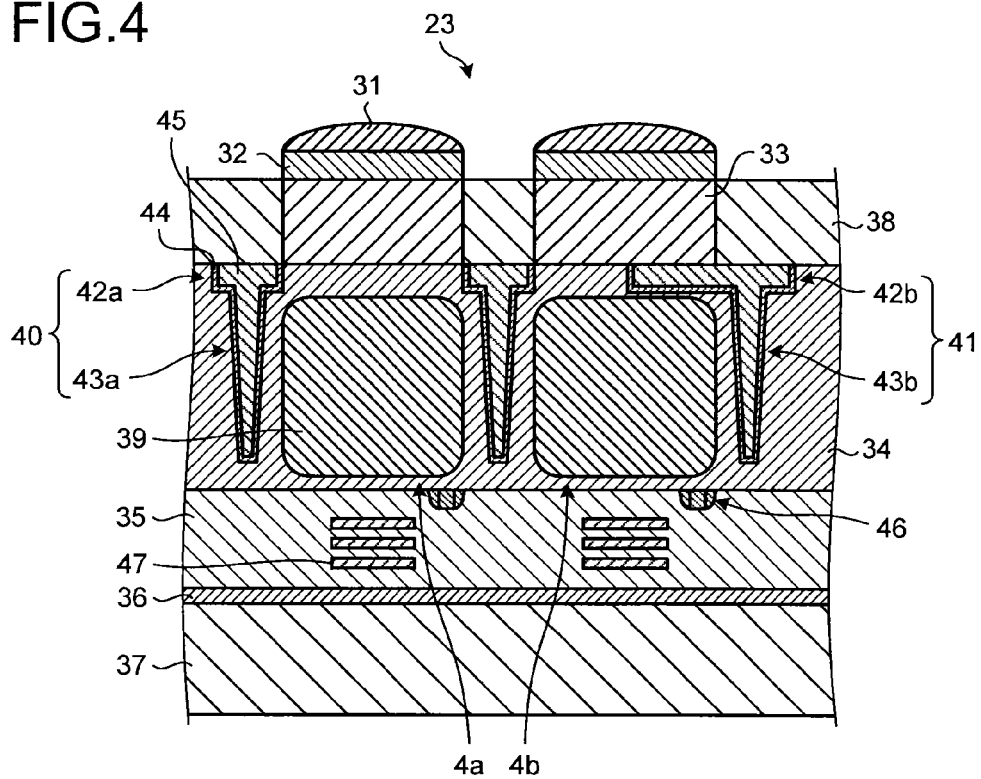


FIG.5A

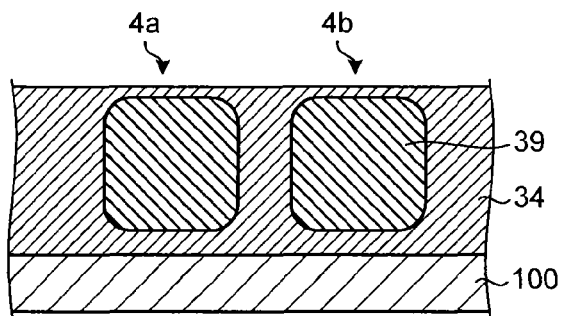


FIG.5B

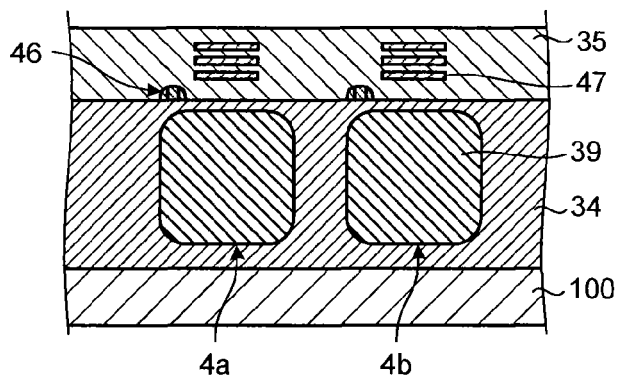


FIG.5C

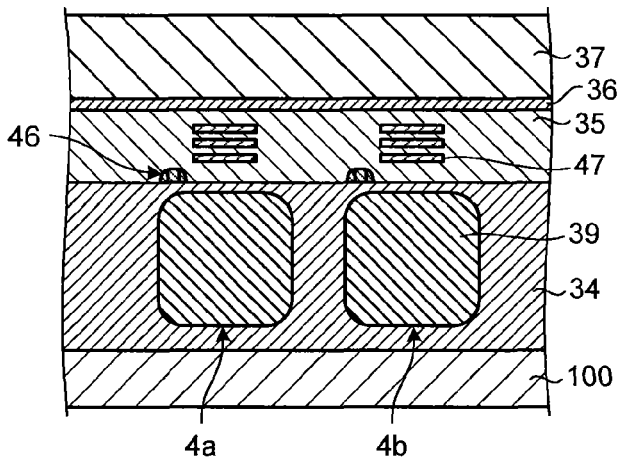


FIG.5D

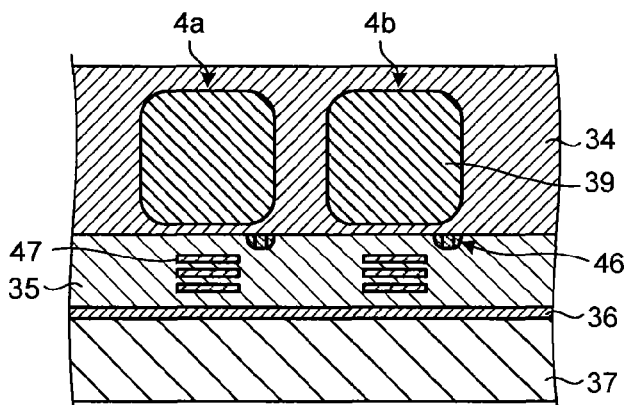


FIG.6A

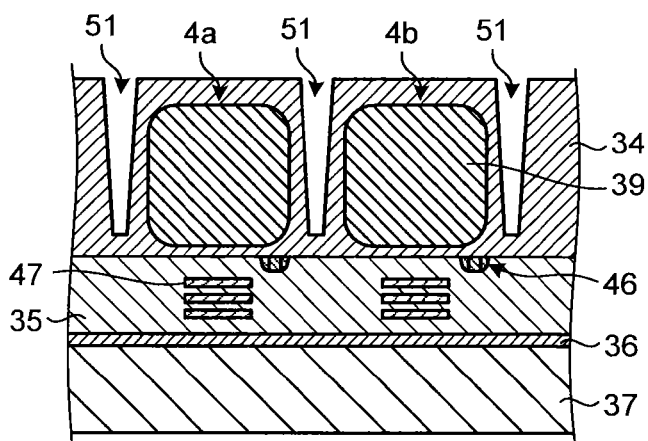


FIG.6B

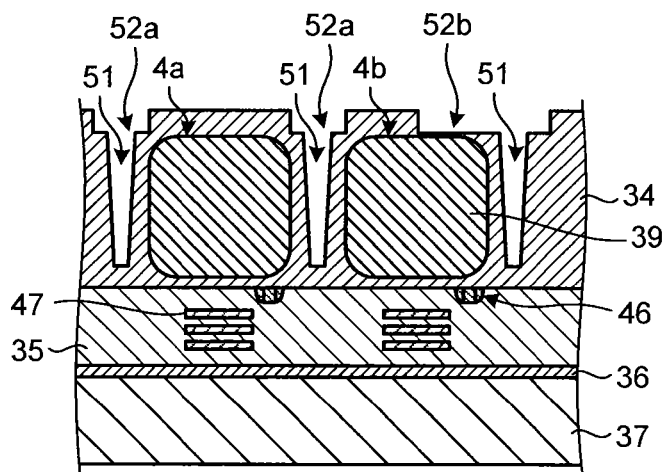


FIG.6C

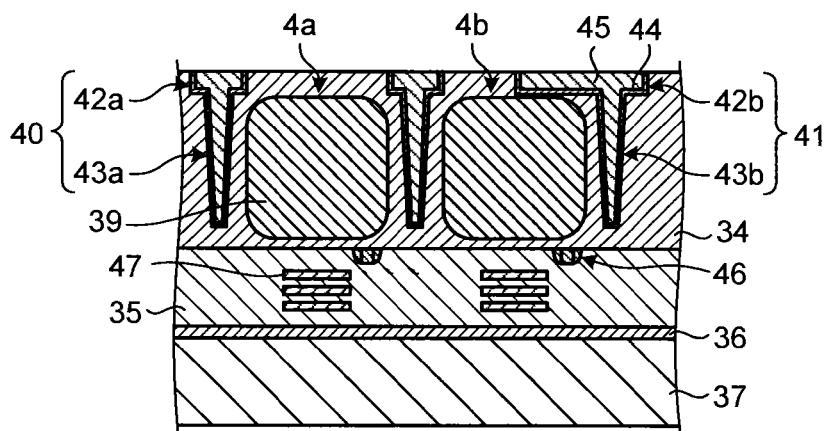


FIG.7A

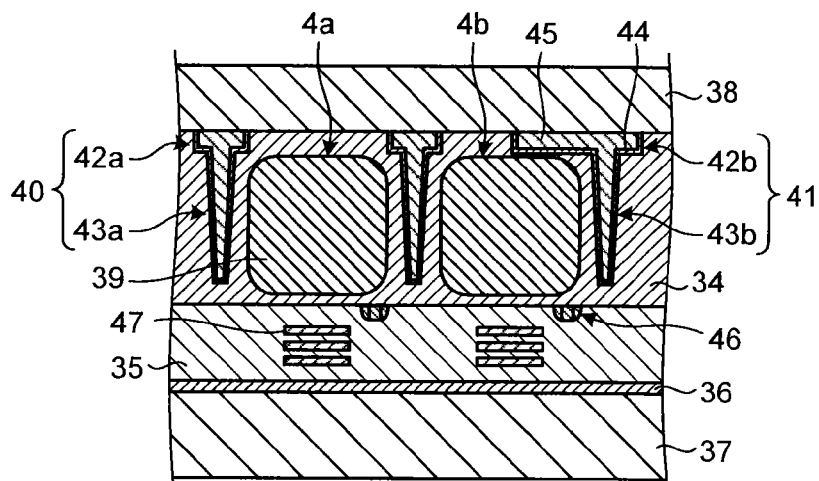


FIG.7B

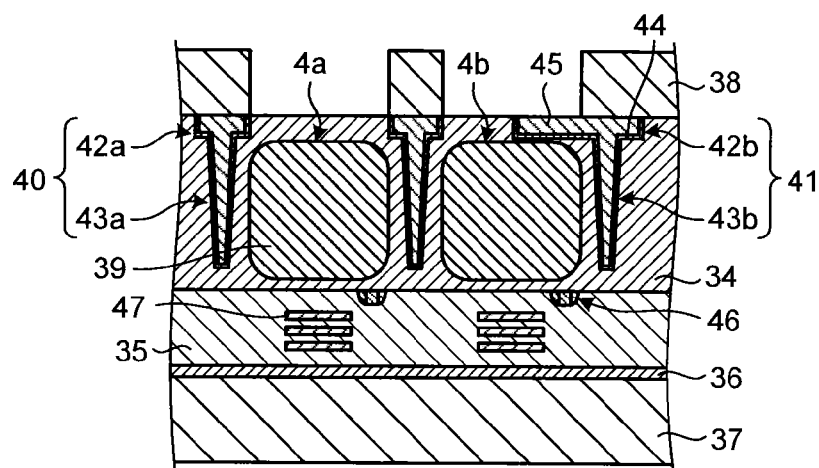


FIG.7C

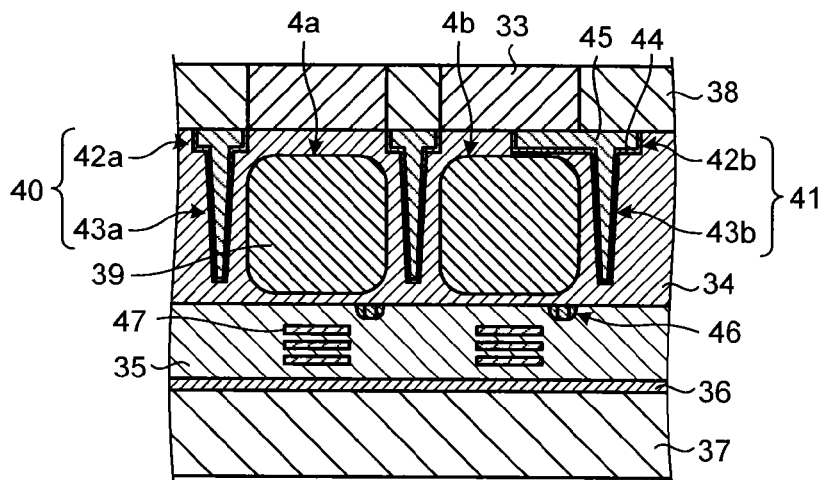
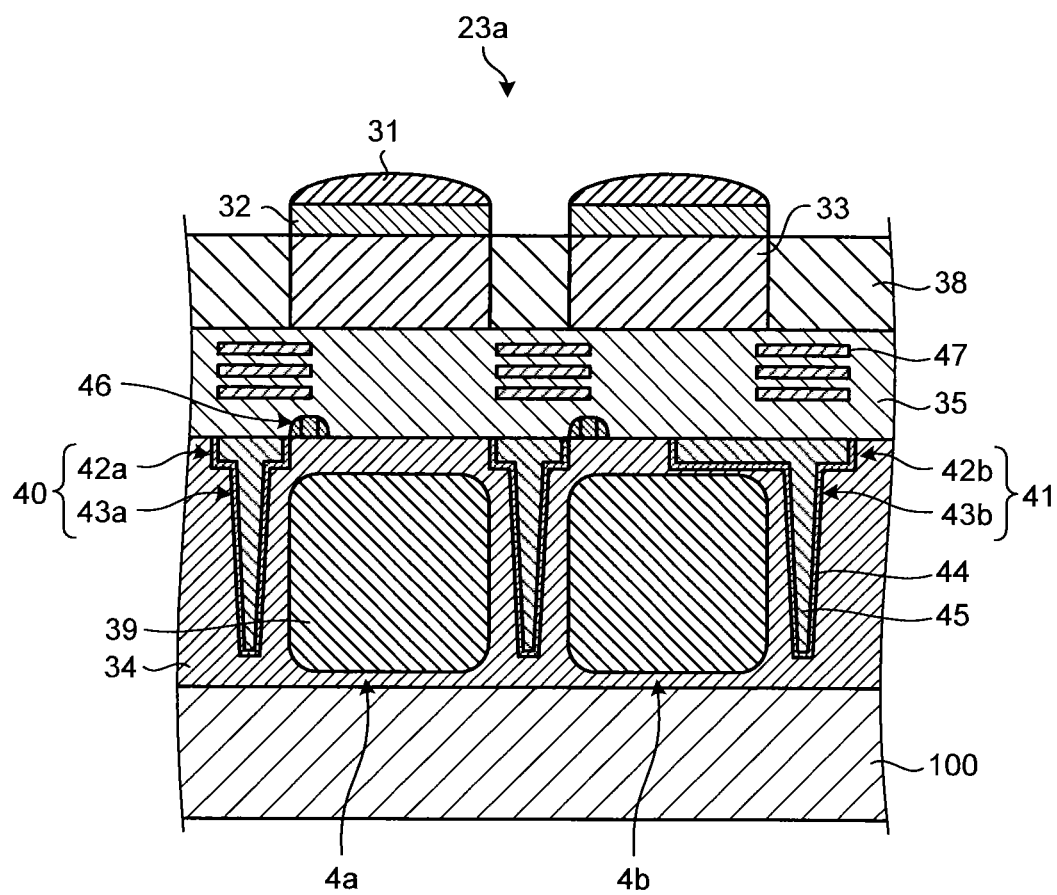


FIG.8



1

**SOLID STATE IMAGING DEVICE****CROSS-REFERENCE TO RELATED APPLICATION**

This application is based upon and claims the benefit of priority from Japanese Patent Application No. 2013-159906, filed on Jul. 31, 2013; the entire contents of which are incorporated herein by reference.

**FIELD**

Embodiments described herein relate generally to a solid state imaging device, and a method of manufacturing a solid state imaging device.

**BACKGROUND**

Conventionally, an electronic device such as a digital camera or a mobile terminal with camera includes a camera module having a solid state imaging device. The solid state imaging device has multiple photoelectric conversion elements arranged two-dimensionally corresponding to each pixel of a captured image.

Each of the photoelectric conversion elements is provided on a semiconductor layer. It photoelectrically converts light, which is incident through an insulating layer, a color filter, and a microlens stacked on the side of the semiconductor layer where light enters, into charges in an amount according to the amount of the received light, and stores the charges as signal charges indicating brightness of each pixel. A light shielding portion for shielding light incident from a specific direction on each photoelectric conversion element is provided in the insulating layer formed between the photoelectric conversion element and the color filter.

For example, the photoelectric conversion element for detecting a phase difference formed for detecting a focus of an imaging optical system has a light shielding portion provided on its light receiving surface for covering a part of the light receiving surface in order to pupil-divide the incident light. A light shielding portion that shields light incident from the color filter corresponding to the adjacent photoelectric conversion element is provided between the photoelectric conversion elements used for the image capture, viewed from the side where light enters.

In the solid state imaging device described above, the incident light might irregularly reflect on the side face of the light shielding portion to deteriorate light-receiving sensitivity. If the light shielding portion is made thin, the irregular reflection can be reduced. However, a part of a fine pattern on the light shielding portion might be lost due to electric or mechanical stress. On the other hand, when the light shielding portion is made thick, flatness is difficult to secure, so that an air bubble called a void is generated in the insulating layer during a step of burying the light shielding portion with the insulating layer. Such void causes deterioration in the light-receiving sensitivity.

**BRIEF DESCRIPTION OF THE DRAWINGS**

FIG. 1 is a block diagram illustrating a schematic configuration of a digital camera having a solid state imaging device according to an embodiment;

FIG. 2 is a block diagram illustrating a schematic configuration of the solid state imaging device according to the embodiment;

2

FIG. 3 is an explanatory view illustrating a shape of a light shielding portion and a phase difference pattern according to the embodiment;

FIG. 4 is an explanatory view schematically illustrating a cross-section taken along a line A-A' in FIG. 3;

FIGS. 5A to 7C are cross-sectional views schematically illustrating a manufacturing process of the solid state imaging device according to the embodiment; and

FIG. 8 is an explanatory view when the light shielding portion and the phase difference pattern according to the embodiment are employed for a front surface irradiation type image sensor.

**DETAILED DESCRIPTION**

In general, according to one embodiment, a solid state imaging device includes a semiconductor layer, and a light shielding portion. The semiconductor layer has multiple photoelectric conversion elements that are arranged in a two-dimensional array. The light shielding portion is provided in the semiconductor layer, and has a light shielding member whose interface with the semiconductor layer is covered by an insulating film. The light shielding portion includes a light shielding region and an element isolation region. The light shielding region is provided in the semiconductor layer on the side close to the light receiving surface of the photoelectric conversion element for shielding light incident on the photoelectric conversion element from a specific direction. The element isolation region is formed to project in the depth direction of the semiconductor layer from the light shielding region toward a portion between the multiple photoelectric conversion elements in order to electrically and optically isolate the multiple photoelectric conversion elements from one another.

A solid state imaging device and a method of manufacturing the solid state imaging device according to an embodiment will be described below in detail with reference to the accompanying drawings. The present invention is not limited to the embodiment.

FIG. 1 is a block diagram illustrating a schematic configuration of a digital camera 1 including a solid state imaging device 14 according to the embodiment. As illustrated in FIG. 1, the digital camera 1 includes a camera module 11 and a post-processing unit 12.

The camera module 11 includes an imaging optical system 13 and the solid state imaging device 14. The imaging optical system 13 takes light from a subject to image a subject image. The solid state imaging device 14 captures the subject image, imaged by the imaging optical system 13, and outputs an image signal obtained by the image-capture to the post-processing unit 12.

The solid state imaging device 14 generates a control signal that automatically adjusts a focus of the imaging optical system 13, and outputs the generated signal to the imaging optical system 13. The camera module 11 mounted to the digital camera 1 is also applied to an electronic device such as a mobile terminal with camera.

The post-processing unit 12 includes an ISP (Image Signal Processor) 15, a storage unit 16, and a display unit 17. The ISP 15 performs a signal process to the image signal inputted from the solid state imaging device 14. The ISP 15 executes a high-quality process including a noise eliminating process, a defective pixel correcting process, and a resolution converting process.

The ISP 15 outputs the image signal, which has undergone the signal process, to the storage unit 16, the display unit 17, and a later-described signal processing circuit (FIG. 2)

mounted in the solid state imaging device **14** in the camera module **11**. The image signal fed back to the camera module **11** from the ISP **15** is used to adjust and control the solid state imaging device **14**.

The storage unit **16** stores the image signal inputted from the ISP **15** as an image. The storage unit **16** also outputs the image signal of the stored image to the display unit **17** according to a user's operation. The display unit **17** displays an image according to the image signal inputted from the ISP **15** or the storage unit **16**. The display unit **17** is a liquid crystal display, for example.

Next, the solid state imaging device **14** mounted to the camera module **11** will be described with reference to FIG. **2**. FIG. **2** is a block diagram illustrating a schematic configuration of the solid state imaging device **14** according to a first embodiment. As illustrated in FIG. **2**, the solid state imaging device **14** includes an image sensor **20**, and the signal processing circuit **21**.

This embodiment describes the case in which the image sensor **20** is a back surface irradiation type CMOS (Complementary Metal Oxide Semiconductor) image sensor having a wiring layer formed on the side reverse to the side where the incident light from the photoelectric conversion element, which photoelectrically converts the incident light, enters.

The image sensor **20** according to the present embodiment is not limited to the back surface irradiation type CMOS image sensor. The image sensor **20** may be any image sensors including a front surface irradiation type CMOS image sensor, and a CCD (Charge Coupled Device) image sensor.

The image sensor **20** includes a peripheral circuit **22** and a pixel array **23**. The peripheral circuit **22** includes a vertical shift register **24**, a timing control unit **25**, a CDS (correlated double sampling unit) **26**, an ADC (analog-digital conversion unit) **27**, and a line memory **28**.

The pixel array **23** is provided on an imaging region of the image sensor **20**. The pixel array **23** has the multiple photoelectric conversion elements mounted on the semiconductor layer and corresponding to each pixel of the captured image. The multiple photoelectric conversion elements are arranged in the horizontal direction (in the row direction) and in the vertical direction (in the column direction) in a two-dimensional array (matrix array). Each photoelectric conversion element on the pixel array **23** generates signal charges (e.g., electrons) according to the amount of the incident light, and stores the generated charges.

The timing control unit **25** is a processing unit outputting a pulse signal, serving as a reference of an operation timing, to the vertical shift register **24**. The vertical shift register **24** is a processing unit outputting to the pixel array **23** a selection signal for selecting, one by one on the column basis, the photoelectric conversion element from which the signal charges are read, out of the multiple photoelectric conversion elements arranged in an array (matrix).

The pixel array **23** outputs the signal charges, which are stored in each of the selected photoelectric conversion elements on the column basis by the selection signal inputted from the vertical shift register **24**, to the CDS **26** from the photoelectric conversion element as a pixel signal indicating brightness of each pixel.

The CDS **26** is a processing unit that eliminates noise from the pixel signal inputted from the pixel array **23** by correlated double sampling, and outputs the resultant to the ADC **27**. The ADC **27** converts the analog pixel signal inputted from the CDS **26** into a digital pixel signal, and outputs the converted signal to the line memory **28**. The line memory **28** temporarily stores the pixel signal inputted from the ADC **27**,

and outputs the held pixel signal to the signal processing circuit **21** for each row of the photoelectric conversion elements.

The signal processing circuit **21** performs a predetermined signal process to the pixel signal inputted from the line memory **28**, and outputs the resultant signal to the post-processing unit **12**. The signal processing circuit **21** performs a signal process, such as a lens shading correction, defect correction, and noise eliminating process, to the pixel signal.

As described above, in the image sensor **20**, the multiple photoelectric conversion elements arranged on the pixel array **23** photoelectrically convert the incident light into the signal charges in an amount corresponding to the amount of the received light, and store the charges, and then, the peripheral circuit **22** reads the signal charges stored in each photoelectric conversion element as the pixel signal. Thus, the image sensor **20** can capture an image.

The pixel array **23** includes a focus-detecting photoelectric conversion element (referred to as "phase difference detecting element" below) provided to detect the focus of the imaging optical system **13** according to a pupil division phase difference detection system. At least two phase difference detecting elements, i.e., a pair of phase difference detecting elements, are provided in the pixel array **23** on a proximate position.

A light shielding portion (referred to as a "phase difference pattern" below) for covering a part of (e.g., a half of) a light receiving region is formed on the light receiving surface of each phase difference detecting element. A light shielding portion is also provided on the light receiving surface of the imaging photoelectric conversion element so as to enclose each photoelectric conversion element as viewed from the light receiving surface.

In the solid state imaging device **14**, the signal processing unit **21** calculates the phase difference of the light received by each phase difference detecting element based upon the signal charges photoelectrically converted by the pair of phase difference detecting elements. The signal processing circuit **21** moves a lens in the imaging optical system **13** to make the calculated phase difference close to the phase difference that is a focusing reference, thereby executing automatic focusing process.

Next, the shape of the light shielding portion and the phase difference pattern on the pixel array **23** will be described with reference to FIG. **3**. FIG. **3** is an explanatory view for describing a shape of a light shielding portion **40** and a shape of a phase difference pattern **41** according to the embodiment. FIG. **3** does not illustrate the components formed on the side closer to the light incident side than to the semiconductor layer on which the imaging photoelectric conversion elements **4a** and the phase difference detecting elements **4b** are formed.

As illustrated in FIG. **3**, multiple photoelectric conversion elements **4a** whose light receiving surfaces are exposed in a rectangular shape viewed from the light incident side are provided on the pixel array **23** in a matrix. On the pixel array **23**, a pair of phase difference detecting elements **4b** whose light receiving surfaces are exposed in a triangular shape viewed from the light incident side is provided to be adjacent to each other. The half of the rectangular light receiving surface of the phase difference detecting element **4b** across the diagonal line of the light receiving surface is covered by the phase difference pattern **41**. Thus, the light receiving surface is exposed in the triangular shape.

The phase difference pattern **41** covers the halves of the light receiving surfaces, symmetric with each other, of the pair of phase difference detecting elements **4b** as described

5

above. With this configuration, the pair of phase difference detecting elements **4b** receives light incident from the oblique direction that inclines at a symmetric angle with respect to the direction perpendicular to the light receiving surface, and pupil-divides the incident light. The signal processing circuit **21** calculates the phase difference of a pair of pupil-divided light, and compares the calculated phase difference and the reference phase difference. Thus, the signal processing circuit **21** can execute automatic focusing.

The light shielding portion **40** is formed in a matrix, viewed from the light incident side, around the photoelectric conversion elements **4a** and the phase difference detecting elements **4b**. The light shielding portion **40** can shield light introducing to each of the photoelectric conversion elements **4a** and the phase difference detecting elements **4b** from the adjacent photoelectric conversion element **4a** or the phase difference detecting element **4b**. An insulating film **44** is formed between the photoelectric conversion element **4a** as well as the phase difference detecting element **4b**, and the light shielding portion **40** as well as the phase difference pattern **41**.

In the present embodiment, the pixel array **23** is formed in order that the light-receiving sensitivity can be enhanced without reducing the thickness of the light shielding portion **40** and the phase difference pattern **41**, those of which shield light. The configuration of the pixel array **23** according to the embodiment will be described below with reference to FIG. 4.

FIG. 4 is an explanatory view schematically illustrating the cross-section along a line A-A' in FIG. 3. FIG. 4 illustrates the components formed on the light incident side from the semiconductor layer on which the imaging photoelectric conversion elements **4a** and the phase difference detecting elements **4b** are formed. A first conductive type will be described as P-type, and a second conductive type will be described as N-type below. However, the first conductive type may be N-type, and the second conductive type may be P-type.

As illustrated in FIG. 4, the pixel array **23** includes, in the order from the light incident side, a microlens **31**, a color filter **32**, a waveguide **33**, a P-type semiconductor (here, Si: silicon) **34**, an insulating layer **35**, an adhesive layer **36**, and a support substrate **37**.

The microlens **31** is a plano-convex lens that collects incident light. The color filter **32** is a filter selectively transmitting any one of color lights of red, green, blue, and white. The waveguide **33** guides the light passing through the color filter **32** to the P-type Si layer **34**, and it is made of silicon nitride, for example. A protection film **38** made of silicon oxide is formed around the waveguide **33**, for example.

The P-type Si layer **34** is, for example, a region formed by epitaxially growing Si having P-type impurities such as boron doped therein. The P-type Si layer **34** may be formed by an ion implantation of P-type impurities into Si wafer.

An N-type Si region **39** is formed in the P-type Si layer **34** where the photoelectric conversion elements **4a** and the phase difference detecting elements **4b** are formed. In the pixel array **23**, a photodiode formed by PN junction of the P-type Si layer **34** and the N-type Si region **39** becomes the photoelectric conversion elements **4a** and the phase difference detecting elements **4b**.

A reading gate **46** for reading signal charges from the photoelectric conversion elements **4a** and the phase difference detecting elements **4b** and a multi-layer wiring **46** are formed in the insulating layer **35**. The adhesive layer **36** and the support substrate **37** will be described later.

In the pixel array **23** according to the embodiment, the light shielding portion **40** and the phase difference pattern **41** are formed in the P-type Si layer **34** close to the light receiving surface, not on the upper layers (light incident side) on the

6

P-type Si layer **34** where the photoelectric conversion elements **4a** and the phase difference detecting elements **4b** are formed.

Specifically, the light shielding portion **40** includes, in the P-type Si layer **34** on the side close to the light receiving surface of the photoelectric conversion element **4a**, a light shielding region **42a** formed between the photoelectric conversion elements **4a** and an element isolation region **43a** formed to project in the depth direction of the P-type Si layer **34** from the light shielding region **42a** to the portion between the N-type Si regions **39**.

The light shielding portion **40** is formed such that a trench is formed in the P-type Si layer **34** on the position where the light shielding region **42a** and the element isolation region **43a** are formed, the inner peripheral surface of the trench is covered by the insulating film **44**, and then, the trench is buried with the light shielding member **45**.

The light shielding region **42a** of the light shielding portion **40** shields light incident from a specific direction upon each of the photoelectric conversion elements **4a**, e.g., light incident from the color filter **32** on the adjacent photoelectric conversion element **4a**. The element isolation region **43a** electrically and optically isolates the respective photoelectric conversion elements **4a** from one another or isolates the photoelectric conversion element **4a** from the phase difference detecting element **4b**.

The phase difference pattern **41** includes a light shielding region **42b** formed on the position covering a part (here, a half) of the light receiving surface of the phase difference detecting element **4b**, and an element isolation region **43b** formed to project in the depth direction of the P-type Si layer **34** from the light shielding region **42b** to the portion between the N-type Si regions **39**.

The phase difference pattern **41** is formed such that a trench is formed in the P-type Si layer **34** on the position where the light shielding region **42b** and the element isolation region **43b** are formed, the inner peripheral surface of the trench is covered by the insulating film **44**, and then, the trench is buried with the light shielding member **45**.

The light shielding region **42b** of the phase difference pattern **41** shields light incident from a specific direction upon each of the phase difference detecting elements **4b**, e.g., light incident from the oblique direction inclined at a predetermined angle with respect to the direction perpendicular to the light receiving surface. The element isolation region **43b** electrically and optically isolates the phase difference detecting elements **4b** from each other or isolates the phase difference detecting element **4b** from the photoelectric conversion element **4a**.

As described above, the pixel array **23** has the light shielding regions **42a** and **42b** in the P-type Si layer **34**, in which the photoelectric conversion elements **4a** and the phase difference detecting elements **4b** are formed, on the side close to the light receiving surface. Therefore, even if the incident light irregularly reflects on the side face of the light shielding regions **42a** and **42b** on the pixel array **23**, the irregular reflection occurs on the position closer to the photoelectric conversion elements **4a** and the phase difference detecting elements **4b** than in the case where the light shielding portion is formed on the upper layers on the P-type Si layer **34**.

Accordingly, the pixel array **23** can efficiently receive light, which is irregularly reflected on the side face of the light shielding regions **42a** and **42b**, by the photoelectric conversion elements **4a** and the phase difference detecting elements **4b**, thereby being capable of enhancing light-receiving sensitivity.

Since the pixel array **23** can efficiently receive light that is irregularly reflected on the side face of the light shielding regions **42a** and **42b**, the light shielding regions **42a** and **42b** do not have to be thinned. Therefore, the pixel array **23** can prevent the elimination of the pattern on the light shielding regions **42a** and **42b** caused by reducing the thickness of the light shielding regions **42a** and **42b**.

In the pixel array **23**, the light shielding portion **40** and the phase difference pattern **41** are formed in the P-type Si layer **34**. Therefore, the flatness of the top surface, which serves as the light receiving surface, of the P-type Si layer **34** can be secured. Thus, the pixel array **23** can prevent the generation of void in the waveguide **33** and the protection film **38** upon forming the waveguide **33** and the protection film **38** on the upper layers on the P-type Si layer **34**, thereby being capable of preventing the deterioration in the light-receiving sensitivity caused by the void.

A method of manufacturing the solid state imaging device **14** according to the embodiment will be described with reference to FIGS. **5A** to **7C**. The method of manufacturing the components of the solid state imaging device **14** other than the pixel array **23** is the same as a general CMOS image sensor. Therefore, the method of manufacturing the pixel array **23** in the solid state imaging device **14** will only be described below.

FIGS. **5A** to **7C** are cross-sectional views schematically illustrating a manufacturing process of the solid state imaging device **14** according to the embodiment. FIGS. **5A** to **7C** selectively illustrate the manufacturing process of the portion illustrated in FIG. **4** in the pixel array **23**.

As illustrated in FIG. **5A**, upon manufacturing the pixel array **23**, the P-type Si layer **34** is formed on a semiconductor substrate **100** such as a Si wafer. The P-type Si layer **34** is formed by epitaxially growing the Si layer, into which P-type impurities such as boron are doped, on the semiconductor substrate **100**. The P-type Si layer **34** may be formed by the ion implantation of the P-type impurities into the Si wafer, and performing an annealing process.

Then, N-type impurities such as phosphor are injected by the ion implantation into the position on the P-type Si layer **34** where the photoelectric conversion element **4a** and the phase difference detecting element **4b** are to be formed, and then, the annealing process is performed. Thus, the N-type Si region **39** is formed. According to the process described above, the photoelectric conversion element **4a** and the phase difference detecting element **4b**, serving as photodiodes, are formed on the pixel array **23** by the PN junction between the P-type Si layer **34** and the N-type Si region **39**.

Thereafter, as illustrated in FIG. **5B**, the insulating layer **35** is formed together with the reading gate **46** and the multi-layer wiring **47** on the P-type Si layer **34**. During this process, after the reading gate **46** is formed on the top surface of the P-type Si layer **34**, a process of forming a silicon oxide layer, a process of forming a predetermined wiring pattern on the silicon oxide layer, and a process of forming the multi-layer wiring **47** by burying Cu into the wiring pattern are repeated. Thus, the insulating layer **35** having the reading gate **46** and the multi-layer wiring **47** formed therein is formed.

Next, as illustrated in FIG. **5C**, an adhesive agent is applied on the top surface of the insulating layer **35** to form the adhesive layer **36**, and the support substrate **37** such as a Si wafer is adhered onto the top surface of the adhesive layer **36**. Thereafter, the structure is turned upside down as illustrated in FIG. **5D**. Then, the semiconductor substrate **100** is polished from the back side (here, from the top surface) by a polishing device such as a grinder until the semiconductor substrate **100** has a predetermined thickness.

The back side of the semiconductor substrate **100** is further polished by, for example, a CMP (Chemical Mechanical Polishing) in order to expose the back surface (here, the top surface) serving as the light receiving surface of the P-type Si layer **34** as illustrated in FIG. **5D**.

Then, a first trench **51** is formed by, for example, RIE (Reactive Ion Etching) on the position where the element isolation regions **43a** and **43b** (see FIG. **4**) are to be formed in the P-type Si layer **34**, i.e., on the position between the N-type Si regions **39**, as illustrated in FIG. **6A**.

As illustrated in FIG. **6B**, the width of the first trench **51** on its top end is increased to form a second trench **52b** on the position where the light shielding region **42a** (see FIG. **4**) is to be formed and to form a second trench **52b** on the position where the light shielding region **42b** (see FIG. **4**) is to be formed.

It is preferable that the second trench **52a** has a width not overlapping with the outer periphery of the N-type Si region **39** viewed from top, and is flush with the top surface of the N-type Si region **39** or has almost the same depth of the N-type Si region **39** in the P-type Si layer **34** viewed from the cross-section. In other words, the second trench **52a** is formed on the position enclosing the outer periphery of the light receiving surface of the imaging photoelectric conversion element **4a**.

The second trench **52b** is formed to have a width overlapping with a part (here, a half) of the top surface of the N-type Si region **39** in the phase difference detecting element **4b** viewed from top, and to be flush with the top surface of the N-type Si region **39** or to have almost the same depth as the N-type Si region **39** in the P-type Si layer **34** as viewed from cross-section.

Thereafter, as illustrated in FIG. **6C**, the insulating film **44** made of silicon oxide, for example, is formed on the inner peripheral surfaces of the first trench **51** and the second trenches **52a** and **52b** according to the CVD (Chemical Vapor Deposition) or sputtering. The light shielding member **45** such as aluminum is buried in the first trench **51** and the second trenches **52a** and **52b**, covered by the insulating film **44** on their inner peripheral surfaces, according to the CVD.

With this process, the light shielding portion **40** including the light shielding region **42a** and the element isolation region **43a**, and the phase difference pattern **41** including the light shielding region **42b** and the element isolation region **43b** can simultaneously be formed. The insulating film **44** may be the other insulating film such as a silicon nitride film. The light shielding member **45** may be other metals having light shielding property, such as tungsten or copper. The light shielding member **45** may be an insulating material, such as silicon oxide or silicon nitride, having refractive index different from that of Si.

As described above, the light shielding portion **40** and the phase difference pattern **41** are formed in the P-type Si layer **34** on which the photoelectric conversion element **4a** and the phase difference detecting element **4b** are formed in the present embodiment. Therefore, the flatness of the light receiving surface (top surface) of the P-type Si layer **34** can be secured.

In the present embodiment, the top surfaces of the light shielding regions **42a** and **42b** match the top surface of the P-type Si layer **34**, and the lower surfaces thereof are flush with the top surface of the N-type Si region **39** or they have almost the same depth as the N-type Si region **39**. This configuration can make the side faces of the light shielding regions **42a** and **42b** close to the PN junction between the top surface of the N-type Si region **39** and the P-type Si layer **34** as much as possible.

Accordingly, even if the incident light irregularly reflects on the side faces of the light shielding regions **42a** and **42b**, the pixel array **23** can allow the photoelectric conversion element **4a** and the phase difference detecting element **4b** to receive almost all the irregularly reflected light, thereby being capable of enhancing the light-receiving sensitivity.

Next, as illustrated in FIG. 7A, the protection film **38** is formed on the top surface of the P-type Si layer **34** by stacking the silicon oxide with the CVD. As illustrated in FIG. 7B, the protection film **38** on the photoelectric conversion element **4a** and the phase difference detecting element **4b** is selectively removed.

As illustrated in FIG. 7C, silicon nitride is stacked in the opening formed by selectively removing the protection film **38** with the CVD, in order to form the waveguide **33**. The top surface of the P-type Si layer **34** on which the silicon nitride is stacked holds flatness as described above. Therefore, the generation of the void in the waveguide **33** during the process of forming the waveguide **33** is prevented, whereby the deterioration in the light-receiving sensitivity of the pixel array **23** caused by the void can be prevented.

Thereafter, the color filter **32** and the microlens **31** are sequentially formed on the top surface of the waveguide **33**. Thus, the pixel array **23** illustrated in FIG. 4 is formed. In the above description, the image sensor **20** according to the embodiment is the back surface irradiation type image sensor. However, the light shielding portion **40** and the phase difference pattern **41** according to the embodiment are applicable to a front surface irradiation type image sensor.

FIG. 8 is an explanatory view when the light shielding portion **40** and the phase difference pattern **41** according to the embodiment are employed for the front surface irradiation type image sensor. FIG. 8 illustrates a part of a schematic cross-section of a pixel array **23a** in the front surface irradiation type image sensor. The components in FIG. 8 having the same function as the components in FIG. 4 are identified by the same numerals, and the redundant description will not be repeated.

As illustrated in FIG. 8, the pixel array **23a** has the configuration same as the pixel array **23** illustrated in FIG. 4 except that the P-type Si layer **34** is formed on the semiconductor substrate **100**, and the insulating layer **35** in which the reading gate **46** and the multi-layer wiring **47** are formed is arranged on the light receiving surface (top surface) of the P-type Si layer **34**.

Even when the light shielding portion **40** and the phase difference pattern **41** according to the embodiment are applied to the front surface irradiation type image sensor, the internal structure of the P-type Si layer **34** is the same as the pixel array **23** in FIG. 4. Therefore, like the pixel array **23** in FIG. 4, the pixel array **23a** in FIG. 8 can enhance the light-receiving sensitivity without reducing the thickness of the light shielding region **42a** of the light shielding portion **40** and the light shielding region **42b** of the phase difference pattern **41**.

As described above, the solid state imaging device according to the embodiment has the light shielding portion for shielding light incident upon the photoelectric conversion element from a specific direction, the light shielding portion being provided in the semiconductor layer on which the photoelectric conversion element is formed. This configuration can make the side faces of the light shielding portion close to the photoelectric conversion element as much as possible. Accordingly, even if the incident light irregularly reflects on the side face of the light shielding portion, the photoelectric

conversion element can receive almost all the irregularly reflected light, whereby the light-receiving sensitivity can be enhanced.

In the solid state imaging device according to the embodiment, the flatness of the light receiving surface of the semiconductor layer can be secured even without reducing the thickness of the light shielding portion. Therefore, the elimination of the pattern on the light shielding portion caused by the reduction in the thickness of the light shielding portion can be prevented.

In the solid state imaging device according to the embodiment, the flatness of the light receiving surface of the semiconductor layer can be secured. Therefore, the generation of the void in the components formed on the upper layers on the semiconductor layer is prevented, whereby the deterioration in the light-receiving sensitivity of the pixel array **23** caused by the void can be prevented.

While certain embodiments have been described, these embodiments have been presented by way of example only, and are not intended to limit the scope of the inventions. Indeed, the novel embodiments described herein may be embodied in a variety of other forms; furthermore, various omissions, substitutions and changes in the form of the embodiments described herein may be made without departing from the spirit of the inventions. The accompanying claims and their equivalents are intended to cover such forms or modifications as would fall within the scope and spirit of the inventions.

What is claimed is:

1. A solid state imaging device comprising:

a semiconductor layer having multiple photoelectric conversion elements arranged in a two-dimensional array;  
a light shielding portion that is provided in the semiconductor layer, and includes a light shielding member having an interface with the semiconductor layer, the interface being covered by an insulating film, wherein the light shielding portion includes:

a light shielding region that is provided in the semiconductor layer on the side close to a light receiving surface of a photoelectric conversion element of the multiple photoelectric conversion elements for shielding light incident on the photoelectric conversion element from a specific direction; and

an element isolation region that is provided to project in a depth direction of the semiconductor layer from the light shielding region toward a portion between the multiple photoelectric conversion elements in order to electrically and optically isolate the multiple photoelectric conversion elements from one another, wherein

the light shielding region is provided on a position covering a part of the light receiving surface of the photoelectric conversion element that outputs a signal charge for detecting a focus by a pupil division phase difference detection system, out of the multiple photoelectric conversion elements.

2. The solid state imaging device according to claim 1, wherein

the light shielding portion further includes a light shielding region that is provided on a position enclosing the outer periphery of the light receiving surface of the photoelectric conversion element that outputs a signal charge for an image capture, out of the photoelectric conversion elements, in order to shield light incident upon the photoelectric conversion element from a specific direction.

## 11

3. The solid state imaging device according to claim 1, wherein

the photoelectric conversion elements are a photodiode formed of a PN junction between the semiconductor layer of a first conductive type and a semiconductor region of a second conductive type formed in the semiconductor layer,

the light shielding region is formed such that a light receiving surface of the light shielding region coincides with a light receiving surface of the semiconductor layer, and a first depth of a surface opposite to the light receiving surface of the light shielding region is almost the same as a second depth of a light receiving surface of the semiconductor region of the second conductive type formed in the semiconductor layer of the first conductive type, and

the first depth is a depth from the light receiving surface of the light shielding region, and the second depth is a

## 12

depth from the light receiving surface of the semiconductor layer.

4. The solid state imaging device according to claim 1, wherein

the insulating film is a silicon oxide film, and the light shielding member is a metal having light shielding property.

5. The solid state imaging device according to claim 1, further comprising:

a waveguide that is provided on a top surface of the semiconductor layer for guiding incident light to the photoelectric conversion element.

6. The solid state imaging device according to claim 5, wherein the waveguide is made of silicon nitride formed on a position facing the light receiving surface of the photoelectric conversion element, and is enclosed by silicon oxide.

\* \* \* \* \*